

CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-149

Battle Creek Fault Zone

Shasta County, California

by

Theodore C. Smith

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INTRODUCTION

The Battle Creek fault zone, located in southernmost Shasta County, is identified as a Quaternary fault by Jennings (1975). The fault coincides with an "impressive fault-controlled escarpment" (Helley and others, 1981) and reportedly has a long-term displacement rate of 0.2 to 0.5 mm/year during the last 0.45 to 1.0 million years (Clark and others, 1984). The fault is located in the Balls Ferry and Tuscan Buttes NE 7.5-minute and Manton 15-minute quadrangles (see Figure 1).

The Battle Creek fault is being evaluated as part of a state-wide effort to evaluate faults for recency of movement. Those faults determined to be sufficiently active and well-defined are recommended for zoning by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (see Hart, 1980).

This evaluation is limited to review of pertinent literature and a brief survey of the available aerial photographs (U.S. Department of Agriculture, 1952). The limited time available for this analysis precludes any field reconnaissance during this effort.

SUMMARY OF AVAILABLE DATA

Most of the available information about the Battle Creek fault zone is contained in Helley and others (1981) and Harwood and others (1980). According to Helley and others (p. 2), the Battle Creek fault zone consists of several northeast-trending normal faults and coincides with "one of the most impressive fault-controlled topographic features [an escarpment] in the northern Sierran foothills." They describe the fault zone as follows:

"Topographic relief on the escarpment ranges from 45 m (150 ft) at

the [Sacramento] river to a maximum of 485 m (1,600 ft) north of Manton and decreases along strike to the northeast as the downthrown block is buried by volcanic rocks from the east....

"The fault zone is made up of several northeast-trending normal faults that branch and intersect along the course of the escarpment. Except for the faults along the western toe of the escarpment that dip about 50° SE, most faults in the system dip steeply southeast, usually within 10° of vertical. Minor, west-trending faults near Coleman Forebay [Figure 2] dip steeply northwest and appear to be high-angle reverse faults with minor south-side-down displacement. Between Coleman Powerhouse and Black Butte the faults are closely grouped along the escarpment, whereas east of Black Butte the faults are more widely spaced and veer off from the trend of the escarpment to the northwest. The best exposures of the faults and many of the lithologic units are found in the overflow channel of Coleman Forebay.

"Traces of the faults are extremely difficult to locate in the [Pleistocene] fanglomerate between Coleman Powerhouse and Sacramento River. The amount of displacement in that part of the fault zone is unknown, but it must be no more than the topographic relief on the fanglomerate, which is 40 to 45 m (130 to 150 ft). At the overflow channel from Coleman Forebay, the vertical separation on the base of the fanglomerate is about 127 m (420 ft). Vertical separation measured on the base of the basalt at Coleman Forebay, which underlies the fanglomerate of Battle Creek, increases rapidly to the northeast and is about 330 m (1100 ft) at Black Butte and about 440 m (1440 ft) north of Manton.... The amount of strike-slip movement on the faults cannot be established from any geometrical relations observed to date, but the orientation of feather fractures along some faults indicates a component of oblique slip with the south block displaced to the west relative to the north block."

A review of the maps of Helley and others (1981) and Harwood and others (1980) show that the youngest unit they believe is cut by the Battle Creek fault zone is a Pleistocene fan deposit (Qbf) which overlies the basalt of Coleman Forebay (Qcb). Harwood and others and Helley and others indicate that a Pleistocene hypersthene andesite (part of which is older and part younger than the ash of Mount Maïdu [0.45 my]) and a younger, but still Pleistocene, basalt flow at Black Butte (Qbb) are not known to be cut by the fault [legends of both maps indicate that a dotted line symbol is used to portray concealed faults; however, the symbol used on both maps appears to be a very short dashed line]. In fact, Helley and others (p. 3) state that the basalt of Black Butte appears to "...postdate most if not all of the displacement."

In discussing the displacement history of the Battle Creek fault zone, Helley and others (1981, p. 3-4) indicate that "the evidence in hand suggests that the faulting postdates the ash [of Mount Maïdu]" although they state that

this is not absolutely clear. As they relate:

"Except for one outcrop in Ash Creek, all of the ash occurs south of the Battle Creek escarpment [note that Harwood and others (1980) identified this isolated outcrop as another unit, not Maidu Ash].

"The ash of Mount Maidu in Ash Creek is a layer of coarse-sand size pumice fragments 6 to 8 cm thick interlayered with alluvium. It is reworked, water-lain ash deposited by a creek that apparently flowed west-northwest across the area of the Battle Creek escarpment before faulting occurred. It seems most reasonable to suggest that Rancheria Creek was the avenue by which the ash reached Ash Creek before Rancheria Creek was faulted up from its headwaters south of the escarpment and its course blocked by lava and ash from Black Butte. If so, faulting took place in the past 450,000 years [the age of the ash]."

Although Helley and others (1981) appear fairly certain about the amount of late Quaternary displacement which has occurred along the zone in various places [Clark and others (1984) indicate that the quality of the cumulative slip data is "A" and the quality of age data used is "B"], a critical review suggests that their conclusions may not be as strongly supported by the facts as they imply. This is suggested by the fact that some of the sites reported by Clark and others (1984) as locations where slip-rate information was obtained lie more than 0.5 miles south of the Battle Creek fault zone (see Figure 2). Thus, if evidence has been obtained at such distant sites then a substantial amount of folding could account for part of the apparent offset. The validity of the evidence may be question on other grounds, as well.

First, in using the base of the basalt at Coleman Forebay and the base of the overlying fanglomerate, there is no assurance that a uniform, pre-depositional surface existed. The present-day pattern of outcrop of these units south of the Battle Creek fault suggests that the pre-depositional surface was not uniform, but that ridges of older units existed locally. It is possible that the escarpment attributed to fault displacement may have existed prior to the deposition of the Pleistocene fanglomerate which overlies the basalt of Coleman Forebay, and that this ridge kept the ancient stream from flowing northward into the headwaters of Rancheria Creek. This, coupled with the fact that Harwood and others (1980), Helley and others, and Clark and others (1984) apparently used information from widely separated sites to derive slip rates and to estimate cumulative slip, suggests that the displacement rates they derived may represent theoretical maximums rather than approximate, actual slip rates.

The outcrop pattern of the Maidu Ash (highlighted in yellow on Figure 2) east of the Sacramento River suggests that two or three westward-flowing streams existed south of the Battle Creek fault zone. The isolated patch of this deposit, or possibly an equivalent unit, along Ash Creek could have been deposited by a paleo-Rancheria Creek as Helley and others suggest, or perhaps the headwaters of Lack Creek once connected with Ash Creek. The outcrop pattern

of fanglomerate northwest of Coleman Forebay would seem to preclude the possibility that the deposit was deposited by a meandering paleo-Battle Creek. However, for the scenario suggested by Helley and others (1981; see above) to have occurred (specifically, for the headwaters of Rancheria Creek to have been dammed by flows and ash of Basalt Butte) would also require most of the displacement (about 600 to 800 ft of vertical displacement based on the topography and outcrop pattern of Maidu Ash) along the Battle Creek fault zone to have occurred after the headwaters of Rancheria Creek were dammed. Alternately, perhaps the Harwood and others (1980) version is correct -- perhaps this isolated outcrop is not Maidu Ash.

Helley and others (1981) and Harwood and Helley (1982) suggest that the Battle Creek fault zone may extend west of the Sacramento River, and merge with the Sulphur Spring fault in the Coast Ranges (Figure 1). They believe that evidence of the surface trace of the fault has largely been obliterated by modern streams and agricultural activities, but that such evidence exists locally in late Quaternary terraces. However, the map of Harwood and Helley does not support the westward extension of a major, late Quaternary fault since no displacement of the top of the Cretaceous is apparent.

Bryant (1982; Appendix A, attached) reports that an attempt to locate the westward extension of the "Battle Creek fault zone" of Helley and others (1981) suggests that the features which Helley and others (1981) concluded were fault-produced topography are actually the margins of terraces along Cottonwood Creek. Bryant also indicates that Terrace 5 (minimum age 250,000 ybp), through or beneath which the fault zone would have to pass, apparently is not offset.

INTERPRETATION OF AERIAL PHOTOGRAPHS

U.S. Department of Agriculture (1952) aerial photographs were briefly reviewed for the purpose of detecting features indicative of recent fault rupture. During this analysis, several well-defined scarps were detected locally. However, these scarps do not coincide with any strands of the Battle Creek fault zone delineated by Harwood and others (1980) or Helley and others (1981). The possibility exists that these scarps are fault-produced features, landslide features, or the edges of volcanic flows.

The general escarpment reported by Helley and others (1981) was verified. However, the faults on this escarpment are not well expressed, and do not exhibit clear evidence of major dip-slip movement during Holocene or even latest Pleistocene time. In fact, the basalt flow of Black Butte (Qbb on Figure 2) appears to cross the escarpment without any evidence of well-defined fault scarps across the flow. Similarly, the hypersthene andesite flow of Brokeoff Mountain lacks any well-defined scarps. Instead, it appears that the basalt and the hypersthene andesite probably flowed down pre-existing escarpments. Thus, significant movement along the fault zone probably predates the basalt and hypersthene andesite flows.

As Helley and others (1981) indicate, no well-defined scarps were evident

in the Pleistocene fanglomerate (Qbf) at the west end of the fault as they map it. However, a generally east-trending graben was apparent locally (see Figure 2) within the basalt of Coleman Forebay. This graben could reflect the presence of a fault, or could result from lateral collapse of the hillside (landsliding).

SEISMICITY

A brief review of the available seismicity data for the study area did not reveal any clear pattern of seismicity that would support the existence of an active, east-northeast trending fault in the study area. Very few earthquakes occurred near the study area between 1900 and 1974, and those earthquakes are poorly located (Real and others, 1978). In 1881, a M 5.0 earthquake occurred southwest of Red Bluff (Topozada and others, 1981). Also, recent studies have documented seismic events in the general vicinity of the Battle Creek fault, but available maps (Cockerham, 1982; 1983) are too small-scale to interpret.

CONCLUSIONS

It appears that the Battle Creek fault zone consists of several splays of normal, primarily steeply southward-dipping faults. Based on the maps of Harwood and others (1980), the text of Helley and others (1981), and the aerial photographs interpreted, it appears that this zone of faults displaces some Pleistocene units (the basalt of Coleman Forebay, and an overlying fanglomerate) but probably does not offset a late Pleistocene basalt flow near Black Butte and may not displace a Pleistocene hypersthene andesite of Brokeoff Mountain. Therefore, it appears that the latest episode of major displacement predates the Holocene.

It is also evident from the conflicts apparent within Harwood and others (1980) and Helley and others (1981) that the history of movement is poorly understood. An independent review of the maps suggests that some of the assumptions made in the process of estimating cumulative slip and slip rate along the fault may be inappropriate, and may have resulted in higher slip rates than the data warrant.

As Helley and others (1981) indicate, the Battle Creek fault is difficult to detect in the Pleistocene fanglomerate. Based on the aerial photographs, it appears that many individual faults within the zone, as they map it, are not well-defined, except locally. Also, where such faults are well-defined, they do not exhibit clear evidence of Holocene displacement. Some well-defined scarps, which could be fault or landslide scarps, are visible on the aerial photographs in areas underlain by Pleistocene volcanics. None of the references cited in this FER show any faults or landslides in the vicinity of these well-defined scarps.

RECOMMENDATIONS

Based on the information available at this time, the Battle Creek fault zone should not be zoned. A more complete evaluation, including field reconnaissance, should be considered when other faults in northeastern California are evaluated.



THEODORE C. SMITH
Associate Geologist
R.G. 3445, C.E.G. 1029

Reviewed & approved.



EARL W. HART
C.E.G. 935
4/23/84

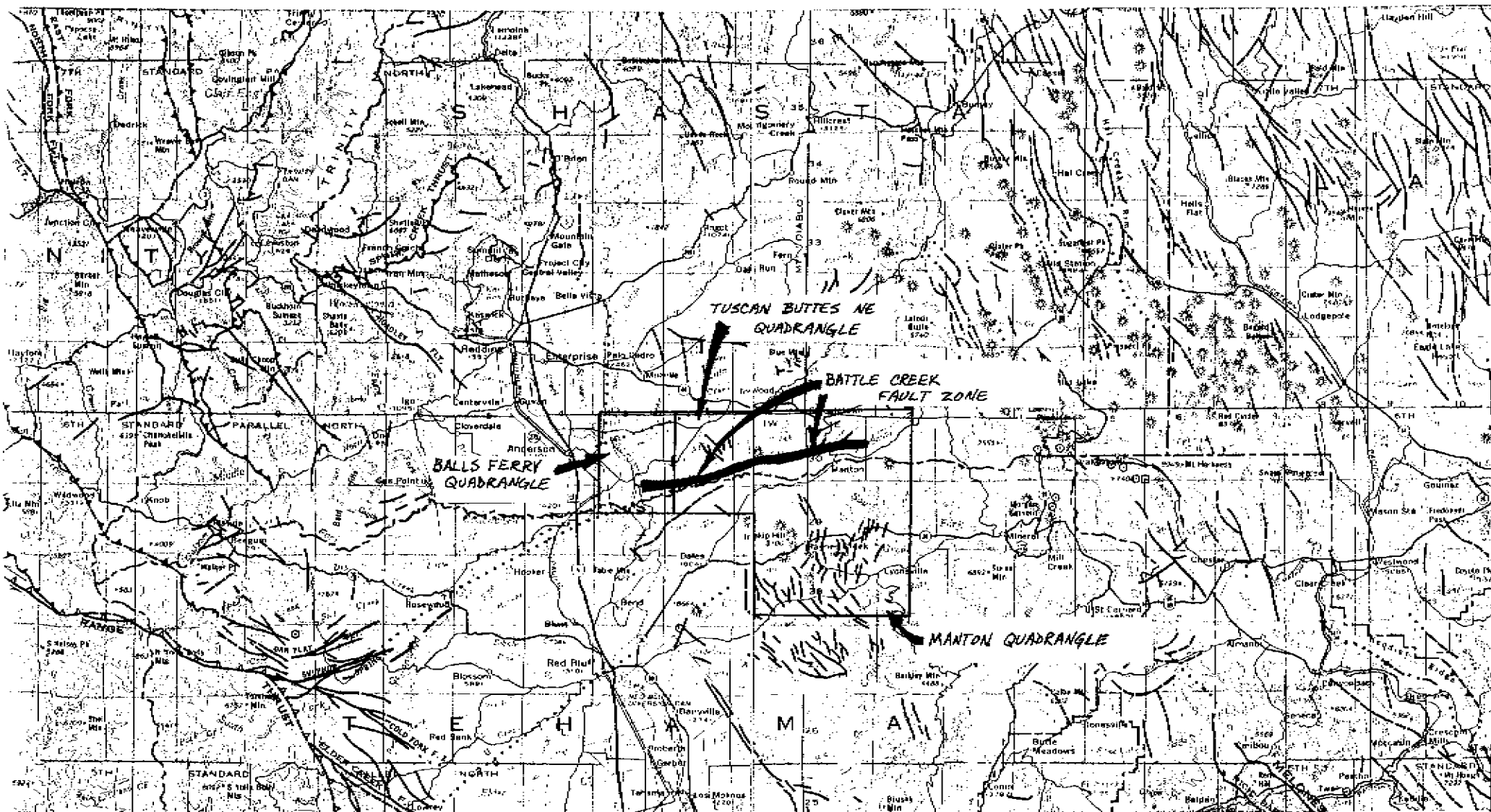
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Map Sheet 39, 1 sheet, scale 1:1,000,000.

Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes: California Division of Mines and Geology Open File Report 81-11 SAC, 182 p.

U.S. Department of Agriculture, 1952, Black and white aerial photographs, BUY series, roll 2K, numbers 196 to 198; roll 5K, numbers 154, 155, 207, and 208; roll 8K, numbers 20 to 22, 125, and 126; roll 11K, numbers 22 to 24, 125 to 127, 134, and 135; and roll 12K, numbers 140 to 142, scale 1:20,000.



FER-149. Figure 1. Location of the Battle Creek fault zone, with appropriate quadrangle coverage indicated. Map modified after Jennings (1975).

Memorandum

To : Perry Amimoto, Advisory Services Officer
California Division of Mines and Geology
1416 Ninth Street, Room 1341
Sacramento, CA 95814

Date: December 9, 1982

From : William A. Bryant, Associate Geologist
Department of Conservation
Division of Mines and Geology
2815 O Street, Sacramento 95816

Subject: Cottonwood Creek Dam Site Investigation

As per your request of December 2, 1982, I represented CDMG at a fault evaluation test trench inspection in the Cottonwood Creek area on December 6 (figure 1). Others participating in the field trip included Ralph Scott and 4 others from DWR, Red Bluff; Guy Hanagan from Division of Safety of Dams, Sacramento; Bob Wright, Doug Hamilton, and one other from Earth Sciences Associates (ESA); Roy Shlemon; Eugene Miller and Gary Van Houghten (sp?) from R.C. Harlan and Associates; and Carl Cole and 2 others from U.S. Army Corps of Engineers (USACE), Sacramento District.

The USACE has proposed the construction of dams along Cottonwood Creek and South Fork Cottonwood Creek, termed the Dutch Gulch and Tehama dam sites, respectively (figure 1). Plio-Pleistocene Tehama Formation underlies most of the dam site area. The Tehama Formation, which generally dips gently east at 0° to 4°, is overlain by nearly flat lying Pleistocene Red Bluff Formation. Younger alluvial deposits occupy the valleys and stream channels.

The Battle Creek fault zone is located east of the proposed dam sites (figure 1). Helley, et al (USGS MF-1298, 1981) mapped Quaternary active traces of the Battle Creek fault zone and have suggested that this fault zone may extend west across the Sacramento River, controlling the drainages of South Fork Cottonwood Creek and Dry Creek. Helley, et al (1981) identify Quaternary terraces thought to be offset by inferred traces of the Battle Creek fault zone. Farther to the west-southwest, photo lineaments mapped by Helley, et al (1981) merge with the Sulphur Springs fault zone of Bailey and Jones (USGS MF-516, 1973) (figure 1).

R.C. Harlan and Associates, consultants to USACE, subcontracted the fault investigation to ESA of Palo Alto. Bob Wright of ESA directed the fault evaluation investigation and served as field trip guide.

Results of the study conclude that photo lineaments mapped by Helley, et al (1981) are not faults, but are inter-level terraces in the Cottonwood Creek drainage area. The Cottonwood Creek area is characterized by relatively complete, well-developed sets of nested terraces. The terraces are cut into Tehama Formation and a veneer of gravels overlie the Tehama Formation. Up to 6 terraces have been recognized by ESA and a detailed Quaternary stratigraphic history has been recorded. Ages of the terraces have been inferred by Roy Shlemon, based on degree of soil development and relative position of the terraces (figure 2, stop #1).

Terrace 5 (minimum age 250,000 years BP) is located at the mouth of Cottonwood Creek on the west side of the Sacramento River. The west-southwest projection of the Battle Creek fault zone would have to pass beneath this terrace. ESA concluded that there is no evidence of displacement of this terrace by the Battle Creek fault. Bob Wright doubts that the Battle Creek fault zone extends west of the Sacramento River.

Selected lineaments inferred by Helley, et al (1981) to be evidence of faulted terrace surfaces were trenched by ESA. No evidence of faulting was observed and ESA interpreted the lineaments (generally breaks in slope) to be inter-level terraces (figure 2, stop #2).

Faulted Tehama Formation was observed in trench exposures near the Sulphur Springs fault zone of Bailey and Jones (1973) (figures 1, 3). Nomlaki Tuff, a 3.3 my old dacite pumice tuff member of the Tehama Formation, occurs near the base of the Tehama Formation and was observed in fault contact with mudstone of the Cretaceous Great Valley Sequence. Farther east along an air photo lineament mapped by ESA, trench excavations (T2 to T4) exposed faulted Nomlaki Tuff (figure 3). The sense of offset is normal, south side down, which is consistent with the sense of displacement observed along the Sulphur Springs fault. Younger deposits overlying the Tehama Formation are sparse at this location, although a possible paleosol overlying the Tehama Formation

in trench T2 did not appear to be offset. No evidence of faulting was observed in trench T5 (figure 3). ESA concluded that the unfaulted Tehama Formation exposed in T5 is stratigraphically higher than the Nomlaki Tuff, indicating that offset along the Sulphur Springs fault dies out sometime after the deposition of Nomlaki Tuff and before deposition of upper Tehama Formation. However, ESA has conservatively estimated that the latest movement along the Sulphur Springs fault is post Nomlaki Tuff, but no younger than 65,000 years BP, based on unfaulted soils exposed in trenches T2-T4.

Carl Cole of USACE stated that a draft report is expected from ESA in January 1983. I requested that, if possible, copies of trench logs be sent to CDMG.

William A. Bryant

William A. Bryant
Associate Geologist

WAB:mlb

cc: John Alfors
Earl Hart✓

Attachment

Stop #1. Break in slope between terrace levels 4 and 5. Terrace 5 has a strongly developed soil profile, with an inferred minimum age of 250,000 years BP. Terrace 4 has a less well developed soil profile and an inferred minimum age of 125,000 years.

Stop #2. Trenches excavated across photo lineaments mapped by Helley, et al. (1981) (southern lineament) and B. Wright of ESA (northern lineament). Only the northern trench (T₁) was open for inspection during the field trip, but the stratigraphic and structural relationships are similar in the southern trenches. T₁ was excavated across a N-facing break in slope suspected to be related to faulting. The trench exposed gravels of terrace 3 to the north and an intermediate level terrace (somewhere between terrace 3 and terrace 4) to the south. Plio-Pleistocene Tehama Fm. exposed in bottom of T₁ - Tehama not offset, and paleosol overlying Tehama is continuous beneath the escarpment. The data from this trench is representative of other trenches excavated across photo lineaments mapped by Helley, et al. (1981) and additional lineaments identified by ESA. No evidence of faulting was observed and it was concluded that many intermediate terrace levels occur in the Cottonwood Creek drainage area.

Figure 2. Field trip stops 1 and 2. Base map from the Anderson 15-minute quadrangle.

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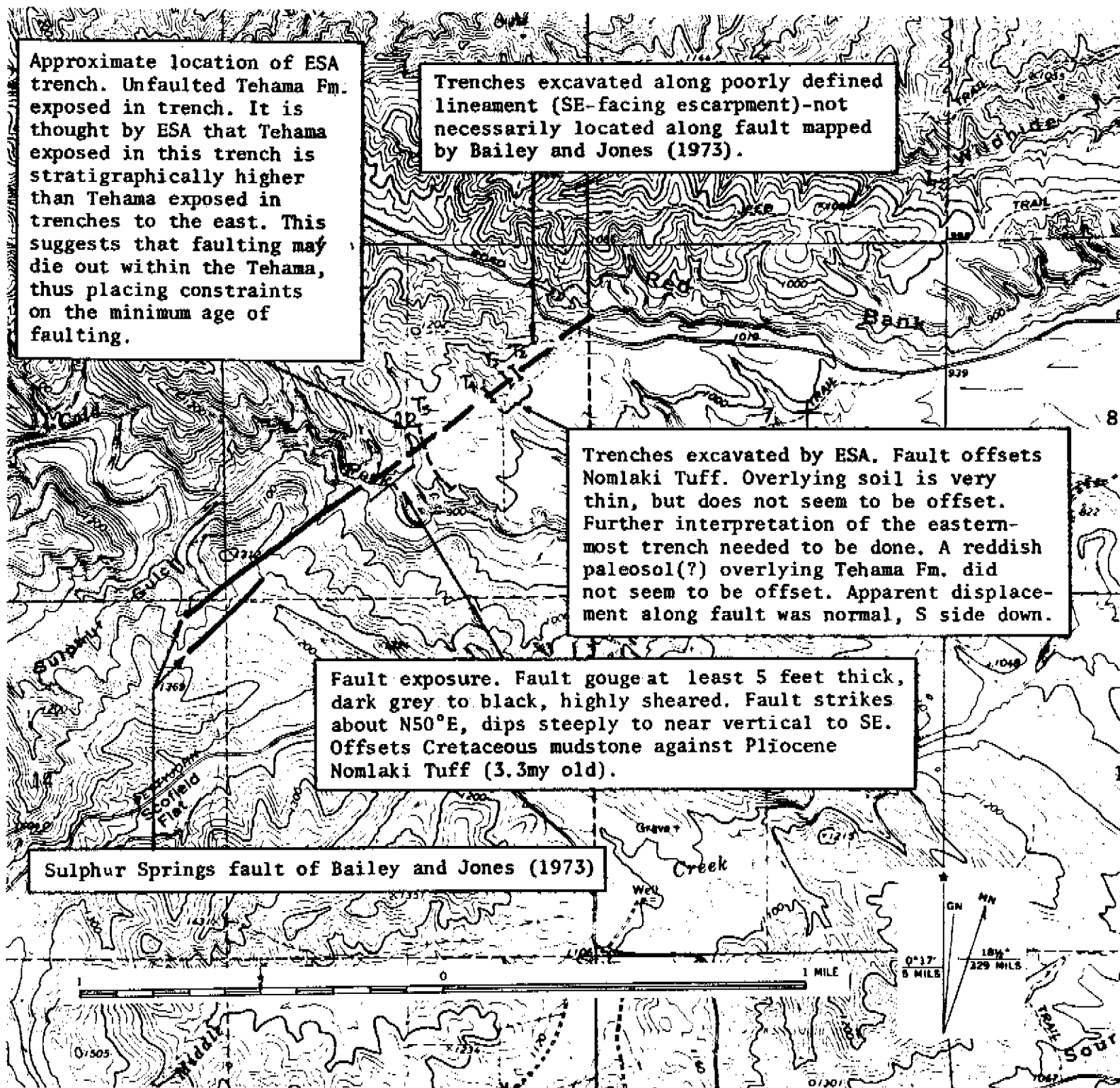


Figure 3. Field trip stop 3. Base map from the Oxbow Bridge 7.5-minute quadrangle.